Recent Catastrophic Decline of Mussels (Bivalvia: Unionidae) in the Little South Fork Cumberland River, Kentucky

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ABSTRACT.— During 1987, we sampled 16 sites in the Little South Fork Cumberland River to assess the status of mussel populations. We found 21 species, of which 12 were alive. Mean densities in the lower one-third of the stream had declined from 2.9 to 7.5 mussels/m^2 in 1981 to 0 to 1.1 mussels/m^2 in 1987. Moreover, we found few live mussels at six other stations in this section of stream. Between 1981 and 1987, two species (*Villosa trabilis* and *Pegias fabula*), listed as federally endangered, appeared to have been extirpated from the lower one-third of the stream. Viable populations of most mussel species are now restricted to the middle section of the Little South Fork. Surface mining of coal has increased in the lower watershed of the Little South Fork in recent years and may be responsible for the mussel decline. Unlike the unionid mussel fauna, the density of the exotic *Corbicula fluminea* has increased nearly ninefold since 1981. This increase appears to be related to the general population expansion of *C. fluminea* in the Cumberland River system.

Harker et al. (1979, 1980) reported on environmental conditions of the Little South Fork Cumberland River (LSF). They considered the stream to have relatively high water quality in comparison with other drainages in the upper Cumberland River basin and to support a fairly speciose flora and fauna. A total of 24 species of unionid mussels were later identified from LSF (Starnes and Bogan 1982); one-third of these species were Cumberlandian endemics, including two that are listed as federally endangered, *Pegias fabula* (Lea, 1838) and *Villosa trabalis* (Conrad, 1834). At the time of its discovery in 1977, this population of *P. fabula* was considered to be the healthiest known, and LSF was "perhaps the most pristine stream remaining within the entire known range of *Pegias* in the Cumberland and Tennessee drainages" (Starnes and Starnes 1980).

Starnes and Bogan (1982), who made an extensive survey of unionids in LSF in 1981, reported qualitative information for the entire

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length of unimpounded river and quantitative data for three sites in the lower 22.8 km of river, which is designated a Kentucky Wild River. The two most common species in their quantitative samples were the Cumberlandian endemics *Ptychobranchus subtentum* (Say, 1825) and *Pegias fabula*. Alhstedt (1986), who examined several sites in LSF in 1984 and 1985, found numerous fresh-dead and relic unionid shells but few living specimens. He observed deposits of silt at one riffle in the lower section of the river, but the source and effects of this siltation apparently were not investigated. Our study was made to determine the present distribution of mussels within LSF, with particular reference to the status of the two endangered species.

MATERIALS AND METHODS

In 1987, we repeated qualitative surveys at the 16 sites (Fig. 1) studied by Starnes and Bogan (1982). At each site we searched for mussels with glass-bottom buckets and by snorkeling. Relic shells (shells showing chalkiness or algal growth on the nacre) and fresh-dead shells were retained; live mussels were identified and returned to the river. Three sites (8, 13, and 16 in Fig. 1) were sampled quantitatively. Ten samples (0.092 m^2) were taken along each of three transects at each site. The samples were collected by removing the substrate from the stream bottom to a depth of about 11 cm and placing the material into the net of a Surber sampler. On shore, the collected substrate was separated with a 4-mm sieve. This procedure differed from the procedure used by Starnes and Bogan (1982) only in that they used a mask and snorkel to search the substrate within the 0.1 m^2 frame *in situ*. Thus, our method may have been more efficient in recovering small unionids and *Corbicula*.

RESULTS

A total of 21 unionid species and the Asian clam, *Corbicula fluminea* (Müller, 1774), were collected (Table 1). The overall species composition determined from shells and live specimens was similar in our study to that reported by Starnes and Bogan (1982). Although we did not collect four species reported by Starnes and Bogan (1982), namely, *Cyclonaias tuberculata* (Rafinesque, 1820), *Anodonta grandis* Say, 1829, *Anodonta imbecillis* Say, 1829, and *Actinonaias ligamentina* (Lamarck, 1819), we collected *Villosa lienosa* (Conrad, 1834), a species not previously reported from LSF. Further, we found more species than did Starnes and Bogan at sites 4, 5, and 7 (Table 1). In contrast, when only live mussels are considered, the results of our sampling differed substantially from those of Starnes and Bogan (1982). We collected more species alive upstream from site 8 than they had, but found substantially fewer species alive at all downstream sites. In fact, most

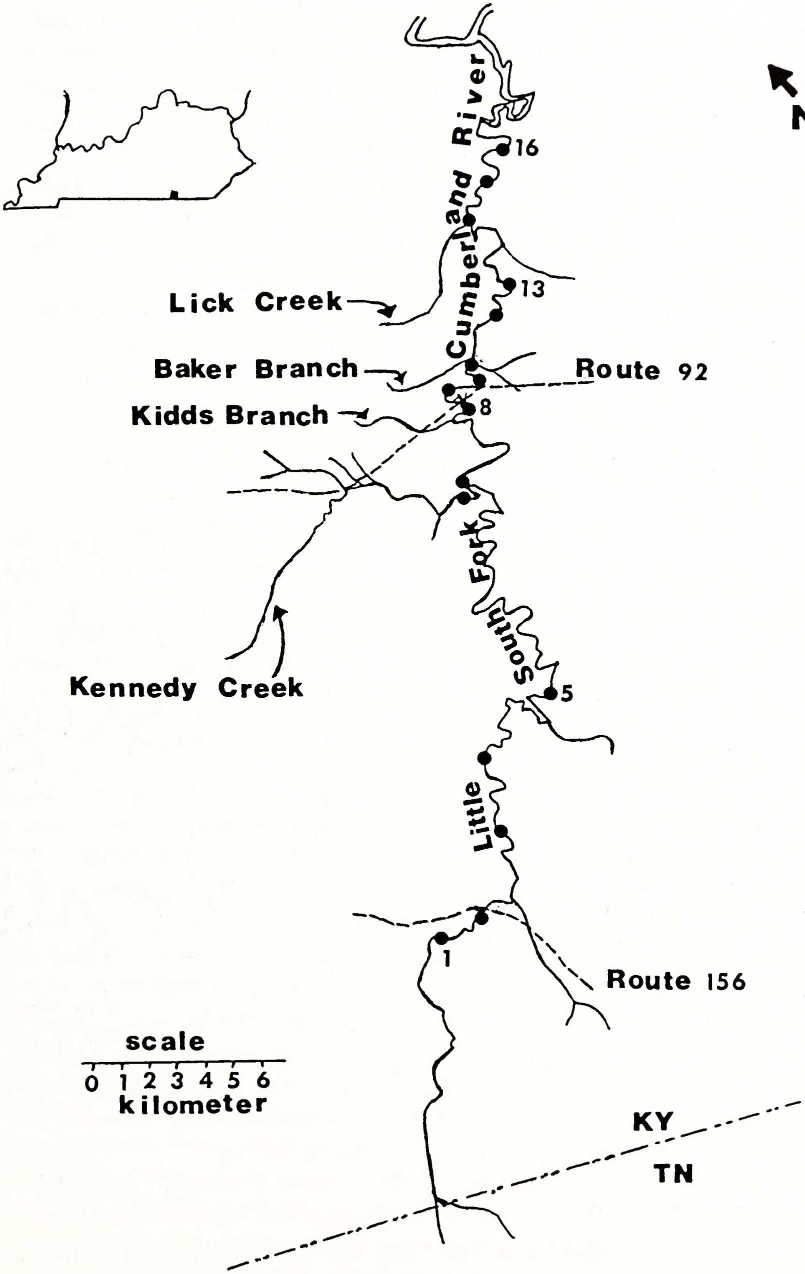

Fig. 1. Map of the Little South Fork Cumberland River, showing the 16 sampling sites. Location of map is shown on inset map of Kentucky.

species were represented by single specimens (which was not true upstream), and at four downstream sites we found no live unionids. Unlike the unionids, *C. fluminea* was found alive at all sites where it had been previously reported, as well as at four additional sites upstream. Data were not collected on other invertebrates or on fishes; however, both were commonly observed throughout the stream.

Our quantitative sampling also indicated that the mussel fauna significantly declined between 1981 and 1987. Apparently there was an almost complete kill of the unionid fauna at sites 8, 13, and 16 (Table 2). *Ptychobranchus subtentum* was the only unionid found alive in the quantitative sampling; three specimens were collected at site 13. Between 1981 and 1987, the density of *C. fluminea* increased markedly at all three sites.

Table 1. Bivalves recorded from the Little South Fork Cumberland River in 1987.[a]

	Stations															
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Alasmidonta viridis (Rafinesque, 1820)		R					R	R				R		R		
Villosa taeniata (Conrad, 1834)[b]			R	L		R	L	R*	R	R	R*	R	L*	R	R	
Lampsilis fasciola Rafinesque, 1820				L*	R		L	R*	*	R	R*	R*	R*	L		R*
Medionidus conradicus (Lea, 1834)				R			R	R*	R		L*	R	L*	R	R	*
Ptychobranchus fasciolaris (Rafinesque, 1820)				R				L*	R*	R*	L*	R	L*	R	R*	*
Ptychobranchus subtentum (Say, 1825)				L		R	R	L*	R*	R	L*	R	L*	R	R	R*
Strophitus undulatus (Say, 1817)				*				R						R		
Villosa iris (Lea, 1829)				L	R	R	L	L		R	R	R	L*	R	R	
Villosa trabalis (Conrad, 1834)				L	L	R	R	R*		*		R	R	R		
Lasmigona costata (Rafinesque, 1820)					L			L*	R	R*	R*		L*	R*	*	R
Pleurobema oviforme (Conrad, 1834)						R	R	R		R			R*	R		
Lampsilis cardia Rafinesque, 1820						R	R*		R	L*		R	R		*	
Toxolasma lividum (Rafinesque, 1831)							L	R	R		R		R*	R		
Alasmidonta marginata Say, 1818								R*			*		R	R		
Elliptio dilatata (Rafinesque, 1820)								R	R	R	L		L*	R	R	*
Leptodea fragilis (Rafinesque, 1820)								R		*	*	*	R	R		
Pegias fabula (Lea, 1838)								R*	R*	R*	R*	R	R*	R*	R	*
Obovaria subrotunda (Rafinesque, 1820)								R*	R	*	R	R	R*	R	R	*
Proptera alata (Say, 1817)								R*		R*	R*	*	R*	R	R*	*
Villosa lienosa (Conrad, 1834)								R								
Actinonaias ligamentina (Lamark, 1819)											*					
Actinonaias pectorosa (Conrad, 1834)											R	R	L	R		
Corbicula fluminea (Miller, 1774)				L	L	L	L	L*	L*	L*	L*	L*	L*	L*	L*	L*

[a]R = relic shells; L = live specimens observed; * = live specimens observed by Starnes and Bogan (1982). Species listing is by first occurrence starting at the most upstream site.

[b]Represents the form listed as *Villosa taeniata punctata* in Starnes and Bogan (1982).

Table 2. Comparison of mussel and *Corbicula* densities (No./m^2) estimated from quantitative samples taken in 1981[a] and in 1987.

Family and year	Station 8	Station 13	Station 16
Unionidae			
1981	7.5	7.2	2.9
1987	0.0	1.1	0.0
Corbiculidae			
1981	46.6	43.7	10.6
1987	366.0	363.8	115.5

[a] 1981 data from Starnes and Bogan (1982)

DISCUSSION

Downstream from site 7, unionid populations have been devastated. Although remnants of the fauna persisted in this section, we saw few live mussels. The decline in these populations is further illustrated by comparing estimated densities with those of Starnes and Bogan (1982) (Table 2). During our survey, only site 13 had mussel populations that were plentiful enough to enable us to estimate population density—1.1 mussels/m^2 compared with 7.2 mussels/m^2 estimated by Starnes and Bogan (1982). Despite the disappearance of unionids, the estimated populations of *C. fluminea* increased about ninefold at all three sites from 1981 to 1987. Although not quantitatively sampled in our study, pleurocerid snail populations were apparently healthy and often dense.

Although the exact cause of the mussel kill in the lower third of LSF is unknown, it is apparent that not all species have been affected to the same degree. In 1981 *P. fabula* was found at densities of 2.2/m^2 at site 8 and was the most abundant mussel at site 16 (Starnes and Bogan 1982). Although we found shells of *P. fabula* at all sites from site 8 downstream to site 15, we failed to find living specimens at these sites. Similarly, *V. trabalis*, which was previously reported alive at two sites, was not found alive in this area. In contrast, *Ptychobranchus subtentum* was the most abundant mussel in both 1981 and 1987. Although it was the mussel most frequently seen alive in the lower section of the stream, its densities were much lower in 1987 than in 1981.

The increase in density of *C. fluminea* in the lower section of LSF and its upstream range extension are in marked contrast to the unionid populations. *Corbicula fluminea* has been invading the Cumberland River and its tributaries for many years (Counts 1986). Apparently it is still colonizing the LSF; however, part of the observed increase in

Corbicula densities may be a result of our greater sampling efficiency, especially in detecting small individuals. Although high densities of *Corbicula* may negatively affect mussels (Clarke 1988), the adverse effects reported usually have occurred at substantially higher *Corbicula* densities than those observed in our study (Gardner et al. 1976). *Corbicula* is generally more tolerant than unionids of environmental stress (Horn and McIntosh 1979). Tolerance to, and even preference for, silted areas by *C. fluminea* has been reported (Belanger et al. 1985). The increase in *Corbicula* densities could be a result of an increasingly favorable substrate.

The source of silt in the LSF has not been documented. However, strip-mining activities have increased greatly since 1981, and heavy siltation has been observed at a few sites within the affected area (S. A. Ahlstedt, personal communication; G. A. Schuster, personal communication). On several occasions we also observed a very fine sediment at Ritner Ford (station 15). These silt deposits varied in depth, with the greatest accumulation occurring along the sides of riffles. Silt deposits appeared to be transient and were readily flushed during freshets.

If the observed silt was a result of strip-mining, it may have contained potentially toxic concentrations of metals such as aluminum or zinc (Dick et al. 1986). "Yellow boy," a ferric precipitate often associated with mining activity, was observed in Lick Creek, Jones Hollow, Baker Branch, and several other unnamed tributaries of LSF. Most of these tributaries are intermittent. Although we never saw yellow boy in the river itself for more than a few meters below a source during low flow, we observed these precipitates to be readily transported during high flows.

The upstream extent of the mussel die-off in LSF appeared to be between sites 6 and 8. Because site 6 is a commonly used ford, the absence of live unionids in 1981 and in 1987 is probably a result of physical disturbance. Moreover, a cursory examination of a riffle just upstream from site 6 indicated the presence of live unionids, including *P. fabula*. All of the tributaries that drain known strip mines in this watershed enter the LSF downstream from site 6. Moreover, the pattern of mining in the LSF appears to be correlated with the sequential die-off of mussels. Intensive mining began in the lower portion of the watershed and has been progressing upstream. In 1981 a rich mussel fauna existed throughout the LSF, and there was relatively little mining. By April 1985, *P. fabula* had been extirpated from sites 13 and 14 but persisted at site 8 (Ahlstedt 1986). In November 1984, a permit was issued to strip-mine 100 ha in the Kidd's Branch sub-basin of the LSF. Kidd's Branch enters LSF between sites 6 and 8. By 1987, *P. fabula* and most other unionids had disappeared from site 8. This pattern of mining activity and the results of our study implicate strip-mining as the cause of the mussel kill. Because unionids are among the most sensitive organisms to acid mine drainage and siltation (Simmons and Reed 1973), their protection may require stricter regulations on strip-mining or increased monitoring of mining activities and better enforcement of existing regulations.

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